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OPTIMIZATION STRATEGIES OF GUARANTEED RESULT FOR INVESTMENT PROJECTING PROCESSES

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In current economic conditions the improvement of investment projecting process is an essential element of efficient control. Investment projecting determines a financial policy of an economic entity as it includes both the development of most profitable means of income acquisition and search for new methods and tools for spare capital investment. In this case the development of the strategy based on investment projecting optimization is an important scientific issue. In the present research matrix games and regression analysis methods are used to make an economic – mathematical control model of an enterprise investment projecting process. The scientific novelty of the research is to develop methods of planned control and to extend the application field of mathematical apparatus of game theory to solve the tasks of optimal employment of recourses under conditions of competitive economic environment. The method to optimize the control of investment projecting suggested in the article allows choosing the best investment projecting strategy. This strategy is considered to be the process of such production output of an enterprise that will be soled with the best guaranteed profitability/risk ratio. The suggested econometric method to choose an optimal control strategy of investment projecting has been used in practice. Features of the suggested method application have been investigated in the case study of a real object of investment projecting, necessary calculations have been made and the obtained results have been analysed. This analysis has revealed the method efficiency to make control decisions when realizing investment projects. The present method may become a foundation for the development of modern tools for investment projecting control in the tasks of strategic optimization. The research is of practical interest for experts in the field of investment and project planning as well as for the specialists who deal with optimal employment of recourses considering the factors of profitability and risk. The research results may be used by any economic entity that implements investment activity and there is no doubt that they will increase its activity efficiency and as a result its competitiveness.

Keyword: investment projecting, control optimization, decision-making, control strategies, optimality criteria, algorithm, pay-off matrix, compromise solution, game theory, guaranteed result.

СТРАТЕГИИ ОПТИМИЗАЦИИ ГАРАНТИРОВАННОГО РЕЗУЛЬТАТА ДЛЯ ПРОЦЕССОВ ИНВЕСТИЦИОННОГО ПРОЕКТИРОВАНИЯ

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В условиях современной экономики совершенствование процесса инвестиционного проектирования является необходимым элементом эффективного управления. Инвестиционное проектирование определяет финансовую политику хозяйствующего субъекта, поскольку предполагает не только разработку наиболее выгодных способов получения доходов, но и поиск новых методов и инструментов инвестирования свободного капитала. В этой связи разработка технологий, основанных на оптимизации инвестиционного проектирования, является весьма актуальной научной проблемой. В данной работе для построения экономико-математической модели процесса управления инвестиционным проектированием предприятия используются методы матричных игр и регрессионного анализа. Научная значимость работы заключается в развитии методов проектного управления и расширении области применения математического аппарата теории игр к решению задач оптимального использования ресурсов в условиях конкурентной экономической среды. Предложенная в ходе исследования методика оптимизации управления процессом инвестиционного проектирования предприятия позволяет реализовать выбор наилучшей стратегии инвестиционного проектирования, под которой понимается процесс формирования такого объема производства предприятия, который будет реализован при наилучшем гарантированном значении соотношения «доходность/риск». Осуществлена практическая реализация предлагаемой эконометрической методики для выбора оптимальной стратегии управления инвестиционным проектированием. На примере реального объекта инвестиционного проектирования рассмотрены особенности применения предложенной методики, выполнены необходимые расчеты и проведен анализ полученных результатов, который показал эффективность методики для выработки управленческих решений при реализации инвестиционных проектов. Данная методика может стать основой для разработки современного инструментария управления процессом инвестиционного проектирования в решении задач стратегической оптимизации. Работа имеет практический интерес для экспертов в области инвестиций и проектного управления, а также широкого круга специалистов, решающих задачи оптимального использования ресурсов с учетом параметров доходности и риска. Результаты исследования могут быть использованы любым хозяйствующим субъектом, осуществляющим инвестиционную деятельность, и, безусловно, повысят эффективность результатов его деятельности и, как следствие, уровень конкурентоспособности.

Ключевые слова: инвестиционное проектирование, оптимизация управления, принятие решений, стратегии управления, критерии оптимальности, алгоритм, платежная матрица, компромиссное решение, теория игр, гарантированный результат.

Introduction

Applied economics faces a lot of difficulties nowadays therefore it is necessary to implement its processes efficiently. Among these processes is investment projecting that elaborates and accomplishes not only the most favourable means to get income but also seeks new profitable options to invest available financial resources.

The development of new economic and mathematical models and methods to optimize the control of investment processes and the creation of the supporting systems of investment decision making based on these models and methods are the important condition for the modern economy operation as it improves the investment climate and increases the benefits from resource investment into promising projects.

A lot of contemporary scientists write about different issues devoted to the implementation of investment projecting. In particular, O.V. Tochilin, E.I. Markovskaya, V.P. Karev research the issues of innovative investment projecting in science-intensive industry; new original models of analysis and forecasting of planned economic systems behaviour are suggested; the issues devoted to the organization of different financial tools that may be used to finance investment projects are discussed; the peculiarities of investment decision making at enterprises and banks are revealed as well [1–6]. Some articles are devoted to control optimization based on gaming technologies [e.g., 7–10]. The further development of models and methods to optimize the control of investment projecting processes is an acute issue.

The main tasks of investment projecting, from the view point of its optimization, are results forecast and the optimization of investment projecting control based on particular qualitative criteria. The present article is devoted to the solution of these tasks. Hence, the scientific practical task and the scientific novelty of the present research are to optimize the strategy of investment projecting. The methodology and the corresponding algorithm of optimal investment projecting strategy, presented in the article, are based on simulation and research of three features of the analyzed process. The suggested strategy optimizes the guaranteed result for these features. Moreover, both statistical data, describing previous periods of enterprise operation, and market research methods are used to forecast prices and sales volume (e.g. when competitors appear, statistical data about them are added).

Methods and performance of the scientific problem of control of investment projecting process

To solve the above mentioned task we suggest using the method implemented within the frameworks of a “games with nature” model. An optimal strategy for investment projecting control is based on this model. Since the sales volume of production (and correspondingly the volume of products manufacture) is one of the investment projecting resources, an optimal investment projecting strategy means the formation such production volume that will be realized with the best guaranteed ratio of profitability/risk values.

To assess the quality of an enterprise development, a set of criteria that are used to choose an optimal strategy to implement investment projecting, is selected. The Wald criterion (the guaranteed result principle) that recommends to apply a maximin strategy, is pessimistic and nature is believed to behave in the worst way for an economic entity. Maximum criteria (principle of optimism) is chosen according to maximax condition, it is optimistic and nature is believed to be the most favourable for the functioning of an enterprise under consideration. The Hurwitz criterion takes an intermediate position that considers both the best and the worst nature behaviour.

It should be noted that separately each of the above mentioned criteria may not be considered to be satisfactory enough to make a final decision about the control optimization of investment projecting process, but their joint analysis allows to visualize the consequences of control decisions and to form the best strategy.

An econometric method to build a model that optimizes the control of investment projecting process has been suggested. This method is based on the theory of optimal control as well as the analysis and modification of economic methods of investment decision result forecast conducted by the authors and described in the works [11–13].

The setting of the task to make investment decision includes the aim determination, the characteristic of future condition of an investment environment and the supposed options of actions. The task solution is to select actions that guarantee the best achievement of the specified aim.

The sales revenue from a company’s products is considered to be a target index. This revenue depends on sales volume, market share and gross return. These indices, in their turn, depend on marketing decisions that determine, first of all, product price.

The condition of external investment environment is determined by possible options of market condition, the expected reaction from competitors to a company action (e.g. increase/decrease of product price), suggested alteration of consumers' preference, etc.

The various options of a decision-maker's actions (DM) are the set of investment measures. Among them are, for example, marketing decisions:

– to reduce the product price by 10%;

– to increase an ad budget by ₽1 million;

– to decrease the price by 5% and to increase an ad budget by ₽ 0.5 million.

Thus, a formal task to optimize decision making during investment projecting may be formulated in the following way. The future of an external investment environment is suggested to be described with the finite number *m* of X_1, X_2, X_3, …, X_m conditions. There is a possible alternative list from *q* marketing decisions of C_1, C_2, C_3, …, C_q. The aim of a decision maker is to form a control strategy that is realized by selecting of one of the possible options that will assure the best (optimal) guaranteed value of the target feature.

Control optimization method of investment projecting process

The present method may be described as an implementation of the following set of actions.

1. The possible control strategies C_i, $i \in \overline{1,q}$, where *q* is the quantity of strategies (scenarios) of an enterprise development and its operation at the market during the period under consideration are formed based on the conducted marketing research data.

A set of purposeful measures is considered to be a strategy to manage an enterprise. This set of measures is characterized by a particular pricing and market policy, expenses rate, ad budget and other factors controlled by an enterprise.

2. Possible market conditions in a *k* arrays form (options corresponding to different conditions of the process implementation) are formed based on the conducted marketing research data. These *k* arrays consist of *m* forecast values $X_i^{(j)} = (X_{1i}^{(j)}, X_{2i}^{(j)}, X_{3i}^{(j)}, X_{mi}^{(j)})$, $j \in \overline{1,k}$, independent variables (factors) $X_{li}^{(j)}$, $l \in \overline{1,m}$ (e.g. these variables assess the inflation rate, products prices sold by competitors, market capacity, etc.), that correspond to possible implementation of a control strategy C_i $(i \in \overline{1,q})$ of an enterprise development and its behaviour at the market during the period under consideration.

Thus, market conditions are considered to be various combinations of external factors independent from an enterprise, i.e. each $X_{li}^{(j)}$ $(l \in \overline{1,m}; i \in \overline{1,q}; j \in \overline{1,k})$ value is a forecast value of the *l*-th factor of a market condition. This value corresponds to a particular control strategy C_i and a forecast option *j*.

3. The data necessary to make multiple regression models are organized based on the results of conducted market researches. This model is the dependence between function values (forecast values of sales volume) that correspond to forecast values of independent variables (factors) and it is used as a forecast model in the form:

$$Y_{ij} = A_i^{(j)} + a_{1i}^{(j)} \times X_{1i}^{(j)} + a_{2i}^{(j)} \times X_{2i}^{(j)} + a_{3i}^{(j)} \times \times X_{3i}^{(j)} + \ldots + a_{3i}^{(j)} \times X_{mi}^{(j)}, \quad (1)$$

where Y_{ij} is a forecasted sales volume corresponding to the implementation of the control strategy (scenario) C_i, $(i \in \overline{1,q})$ and to the array (option) of forecasted values $X_i^{(j)} = (X_{1i}^{(j)}, X_{2i}^{(j)}, X_{3i}^{(j)}, X_{mi}^{(j)})$ $(j \in \overline{1,k})$ of independent variables $X_{li}^{(j)}$, $l \in \overline{1,m}$; $A_i^{(j)}$ is a constant of the corresponding equation of the regression $(l \in \overline{1,m}; j \in \overline{1,k})$; $a_{li}^{(j)}$ is coefficients of the corresponding equation of the regression $(l \in \overline{1,m}; i \in \overline{1,q}; j \in \overline{1,k})$.

Thus, various possible options of the external independent from an enterprise factors implementation are considered to be permissible market conditions. It means that in the equation (1) each $X_{li}^{(j)}$ $(l \in \overline{1,m}; i \in \overline{1,q}; j \in \overline{1,k})$ value is a forecast condition of the market that characterizes, for example, a particular inflation rate, a competitor's pricing policy, market capacity or other external factor independent from an enterprise. This value also corresponds to a possible implementation of a control strategy C_i $(i \in \overline{1,q})$ and a forecast option *j*.

4. Forecast values of sales volume are formed to make a pay-off matrix (Table 1).

Forecast values of sales volume are calculated based on the correlation (1) by means of variation of independent variable values. These values correspond to the content of a great number of suggested control strategies $C = \{C_i\}$, $i \in \overline{1,q}$ and the values of possible market conditions described by corresponding arrays of independent variables $X_i^{(j)} = (X_{1i}^{(j)}, X_{2i}^{(j)}, X_{3i}^{(j)}, X_{mi}^{(j)})$, $j \in \overline{1,k}$; the pay-off matrix of forecasted values of sales volumes $Y = \|Y_{ij}\|$, $i \in \overline{1,q}$, $j \in \overline{1,k}$ is formed according to the formula (1) (Table 1).

Table 1

Elements of a pay-off matrix of forecasted values of sales volumes

Possible control strategies	№ factors array				
	1	**2**	**3**	**…**	***K***
C_1	Y_{11}	Y_{12}	Y_{13}	…	Y_{1k}
C_2	Y_{21}	Y_{21}	Y_{21}	…	Y_{2k}
C_3	Y_{31}	Y_{32}	Y_{33}	…	Y_{3k}
…	…	…	…	…	…
C_q	Y_{q1}	Y_{q2}	Y_{q3}	…	Y_{qk}

5. On the pay-off matrix $Y = \|Y_{ij}\|$, $i \in \overline{1,q}$, $j \in \overline{1,k}$ data basis that is determined by the element values from Table 1 we calculate a maximin estimation of a control strategy. This estimation determines a guaranteed upper bound (guaranteed result) of the forecasted sales value under the worst conditions of the implementation of the process under consideration: $W_* = \max_{i \in \overline{1,q}} \min_{j \in \overline{1,k}} Y_{ij}$, also we calculate the corresponding maximin strategy of control $C_{i_*^{(e)}} \in C$ that meets the following maximin conditions:

$$i_*^{(e)} \in \overline{1,q} : \min_{j \in \overline{1,k}} Y_{i_*^{(e)},j} = \max_{i \in \overline{1,q}} \min_{j \in \overline{1,k}} Y_{ij} = W_* . \qquad (2)$$

6. The pay-off matrix data from table 1 are used to calculate a maximin estimation of a control strategy. This estimation determines the upper bound value of forecasted sales volume when implementing the most favourable situation (a superoptimistic result): $W^* = \max_{i \in \overline{1,q}} \max_{j \in \overline{1,k}} Y_{ij}$. These data are also used to calculate the corresponding maximin strategy of control $C_{i_*^{(e)}} \in C$, that meets the following maximin condition:

$$i^{(e)*} \in \overline{1,q} : \max_{j \in \overline{1,k}} Y_{i^{(e)*},j} = \max_{i \in \overline{1,q}} \max_{j \in \overline{1,k}} Y_{ij} = W^* . \qquad (3)$$

7. To make the compromise solution between superoptimistic estimation W^* and minimax estimation W_*, we calculate the Hurwitz criterion $G_\beta^{(e)}$ value using the formula:

$$G_\beta^{(e)} = \max_{i \in \overline{1,q}} [\beta \times \min_{j \in \overline{1,m}} Y_{ij} + (1-\beta) \times \max_{j \in \overline{1,m}} Y_{ij}], \qquad (4)$$

where β is a fixed pessimism-optimism indicator that is determined by experts based on competitive advantages analysis of an economic entity when $\beta \in [0;1]$. The pessimism-optimism indicator gives the quantitative expression of a decision maker's ideas about the risk of different level, about favourable or neutral environment where the decision maker should choose an optimal strategy. β value is an optimism indicator, and $(1-\beta)$ is a pessimism one. The closer the optimism indicator β to 1 is, the closer to 0 the pessimism indicator $(1-\beta)$ is, and more optimistic and less pessimistic the decision maker is. And vice versa, when $\beta = 1$, the present indicator transforms into a maximax criterion, when $\beta = 0$, it coincides with the Wald maximin criterion. When $\beta = 0.5$, then $(1-\beta) = 0.5$. It means that a decision maker while choosing a strategy behaves neutrally. Responsibility measure influences the choice of the optimism indicator β value. More serious consequences of wrong judgement make a decision maker insure against errors, i.e. the pessimism indicator $(1-\beta)$ is closer to 1. To determine the environment and to analyze the competitive advantages of an enterprise, a decision maker may use, for example, the pay-off matrix of Boston Consulting Group Ltd., or McKinsey Company [14; 15].

8. Based on the Hurwitz criterion (4) we make an optimal compromise control strategy $C_\beta^{(e)} = C_{i^{(e)}} \in C$ that is determined by the $i^{(e)} \in \overline{1,q}$ index and meets the following optimality condition:

$$i^{(e)} \in \overline{1,q} : \beta \times \min_{j\in 1,k} Y_{i^{(e)},j} + (1-\beta)\times \max_{j\in 1,k} Y_{i^{(e)},j} =$$
$$= \max_{i\in 1,q} [\beta \times \min_{j\in 1,k} Y_{ij} + (1-\beta)\times \max_{j\in 1,k} Y_{ij}] = G_{\beta}^{(e)}. \qquad (5)$$

9. When various options have been assessed with several criteria, we make one of the following decisions: 1) when recommendations match, it is more confident to make the best decision; 2) when recommendations contrary to each other, the final decision should be based on its advantages and disadvantages (choose the strategy that is optimal at least for two criteria); 3) if different strategies have been made for all three criteria, the values of the pessimism-optimism indicator should be modified in the Hurwitz criterion or, for example, the data about possible market condition may be changed.

Considering the above mentioned information we suggest the following formalized algorithm to make an econometric method to optimize control process of investment projecting.

Step 0. Initial data formation.

The array of possible control strategies $C = \{C_i\}$, $i \in \overline{1,q}$ is formed, where q is the quality of control strategies (scenarios) applied to plan an enterprise's investment policy and its operation during the period under consideration.

According to the data of the conducted marketing research possible market conditions are made in a form of k arrays (options corresponding to various conditions of the process implementation) that consist of m forecasted values of $X_i^{(j)} = (X_{1i}^{(j)}, X_{2i}^{(j)}, X_{3i}^{(j)}, X_{mi}^{(j)})$, $j \in \overline{1,k}$, independent variables of $X_{li}^{(j)}$, $l \in \overline{1,m}$ that correspond to possible implementation of control strategy of an enterprise investment projecting C_i $(i \in \overline{1,q})$ and the enterprise operation at the market during the period under consideration.

Step 1. Pay-off matrix formation.

The pay-off matrix of forecasted values of sales volumes $Y = \|Y_{ij}\|$, $i \in \overline{1,q}$, $j \in \overline{1,k}$ at the end of the period under consideration is formed. This matrix is based on $(q \times k)$ arrays of forecasted values of the chosen factors $X_i^{(j)} = (X_{1i}^{(j)}, X_{2i}^{(j)}, X_{3i}^{(j)}, X_{mi}^{(j)})$, $j \in \overline{1,k}$, that correspond to the array of admissible control strategies $C = \{C_i\}$, $i \in \overline{1,q}$. It means that Table 1 is completed with the values of elements, each element is calculated according to the formula (1):

$$Y_{ij} = A_i^{(j)} + a_{1i}^{(j)} \times X_{1i}^{(j)} + a_{2i}^{(j)} \times X_{2i}^{(j)} + a_{3i}^{(j)} \times$$
$$\times X_{3i}^{(j)} + ... + a_{3i}^{(j)} \times X_{mi}^{(j)}, i \in \overline{1,q}, j \in \overline{1,k}.$$

Step 2. Formation of a maximin control strategy.

According to (2) we calculate a maximin estimation of the control strategy $W_*^{(e)} = \max_{i\in 1,q} \min_{j\in 1,k} Y_{ij} = \max_{i\in 1,q} W_*(C_i)$, where $W_*(C_i) = \min_{j\in 1,k} Y_{ij}$ and corresponding maximin control strategy $C_{i_*^{(e)}} \in C$, that meets the following maximin conditions:

$$i_*^{(e)} \in \overline{1,q} : \min_{j\in 1,k} Y_{i_*^{(e)},j} = \max_{i\in 1,q} \min_{j\in 1,k} Y_{ij} = \max_{i\in 1,q} W_*(C_i) =$$
$$= W_*(C_{i_*^{(e)}}) = W_*^{(e)}.$$

This strategy is calculated on the pay-off matrix data $Y = \|Y_{ij}\|$, $i \in \overline{1,q}$, $j \in \overline{1,k}$ basis.

Step 3.Formation of a maximax control strategy.

According to (3) we calculate a maximax estimation of the control strategy $W^{(e)*} = \max_{i\in 1,q} \max_{j\in 1,k} Y_{ij} = \max_{i\in 1,q} W^*(C_i)$, where $W^*(C_i) = \max_{j\in 1,k} Y_{ij}$ and the corresponding maximax control strategy $C_{i^{(e)*}} \in C$, that meets the following maximax conditions:

$$i^{(e)*} \in \overline{1,q} : \max_{j\in 1,k} Y_{i^{(e)*},j} = \max_{i\in 1,q} \max_{j\in 1,k} Y_{ij} = \max_{i\in 1,q} W^*(C_i) =$$
$$= W^*(C_{i^{(e)*}}) = W^{(e)*}.$$

This estimation is based on the pay-off matrix $Y = \|Y_{ij}\|$, $i \in \overline{1,q}$, $j \in \overline{1,k}$ data.

Step 4. Formation of the compromise control *strategy.*

For the fixed pessimism-optimism index $\beta \in [0;1]$, according to (4) we calculate the value of the Hurwitz criterion using the formula:

$$G_{\beta}^{(e)} = \max_{i\in 1,q} [\beta \times \min_{j\in 1,m} Y_{ij} + (1-\beta)\times \max_{j\in 1,m} Y_{ij}] = \max_{i\in 1,q} G_{\beta}(C_i),$$

where $G_{\beta}(C_i) = \beta \times \min_{j\in 1,m} Y_{ij} + (1-\beta)\times \max_{j\in 1,m} Y_{ij}$. We also calculate the optimal compromise strategy

$C_\beta^{(e)} = C_{i_\beta^{(e)}} \in C$, that is determined by the $i_\beta^{(e)} \in \overline{1,q}$ index and meets the optimal condition:

$$i_\beta^{(e)} \in \overline{1,q} : \beta \times \min_{j \in \overline{1,k}} Y_{i_\beta^{(e)},j} + (1-\beta) \times \max_{j \in \overline{1,k}} Y_{i_\beta^{(e)},j} =$$
$$= \max_{i \in \overline{1,q}} [\beta \times \min_{j \in \overline{1,k}} Y_{ij} + (1-\beta) \times \max_{j \in \overline{1,k}} Y_{ij}] = \max_{i \in \overline{1,q}} G_\beta(C_i)$$
$$= G_\beta(C_{i_\beta^{(e)}}) = G_\beta^{(e)}.$$

Step 5. Formation of the optimal control strategy.

The optimal strategy $C^{(e)} = C_{i^{(e)}} \in C$ is formed on the basis of organised pairs that contain the strategies formed from the solutions of optimization tasks and the forecasted estimations $(C_{i_*^{(e)}}, W_*^{(e)})$; $(C_{i^{(e)*}}, W^{(e)*})$; $(C_\beta^{(e)}, G_\beta^{(e)})$ corresponding to them. This optimal strategy is determined by the $i^{(e)} \in \overline{1,q}$ index from the condition system:

$$\begin{cases} if\ W_*^{(e)} = W^{(e)*} = G_\beta^{(e)}, then\ i^{(e)} = \\ = i_*^{(e)} \Rightarrow C^{(e)} = C_{i_*^{(e)}}; \\ \begin{cases} if\ (W_*^{(e)} = G_\beta^{(e)}) \vee (W_*^{(e)} = W^{(e)*}) \vee \\ \vee (W^{(e)*} \neq G_\beta^{(e)}), then\ i^{(e)} = i_*^{(e)} \Rightarrow C^{(e)} = C_{i_*^{(e)}}; \\ if\ (W_*^{(e)} = G_\beta^{(e)}) \vee (W_*^{(e)} \neq W^{(e)*}) \vee \\ \vee (W^{(e)*} = G_\beta^{(e)}), then\ i^{(e)} = i_\beta^{(e)} \Rightarrow C^{(e)} = C_{i_\beta^{(e)}}; \\ if\ (W_*^{(e)} \neq G_\beta^{(e)}) \vee (W_*^{(e)} = W^{(e)*}) \vee \\ \vee (W^{(e)*} = G_\beta^{(e)}), then\ i^{(e)} = i^{(e)*} \Rightarrow C^{(e)} = C_{i^{(e)*}}; \end{cases} \\ if\ W_*^{(e)} \neq W^{(e)*} \neq G_\beta^{(e)}, then\ i^{(e)} = \\ = i_\beta^{(e)} \Rightarrow C^{(e)} = C_{i_\beta^{(e)}}. \end{cases}$$

End of the algorithm.

Considering the above mentioned algorithm the flow chart of the present method to optimize the control of investment projecting process is presented in Figure.

Thus, the present algorithm is a detailed consequences of the simulation stages of the decision making process to choose the optimal control strategy of investment projecting. This algorithm may be implemented using computer simulation.

Approbation of the method to optimize the investment projecting control

The practical application of the authors' method to optimize the process of investment projecting control has been approved by the results of its approbation in the business project "Tandem" Ldt. (Ekaterinburg). While choosing an optimal pricing strategy of the present enterprise we considered the marketing research results that revealed that the consumer price index is a key feature of the market condition. In this connection various inflation rates (109%, 110%, 112%, 113%, 115% from the initial rate) are considered to be the "nature" conditions.

The following possible solutions are considered:

Strategy 1: the price is 10% higher than the competitors currently have;

Strategy 2: the price is 5% higher than the competitors currently have;

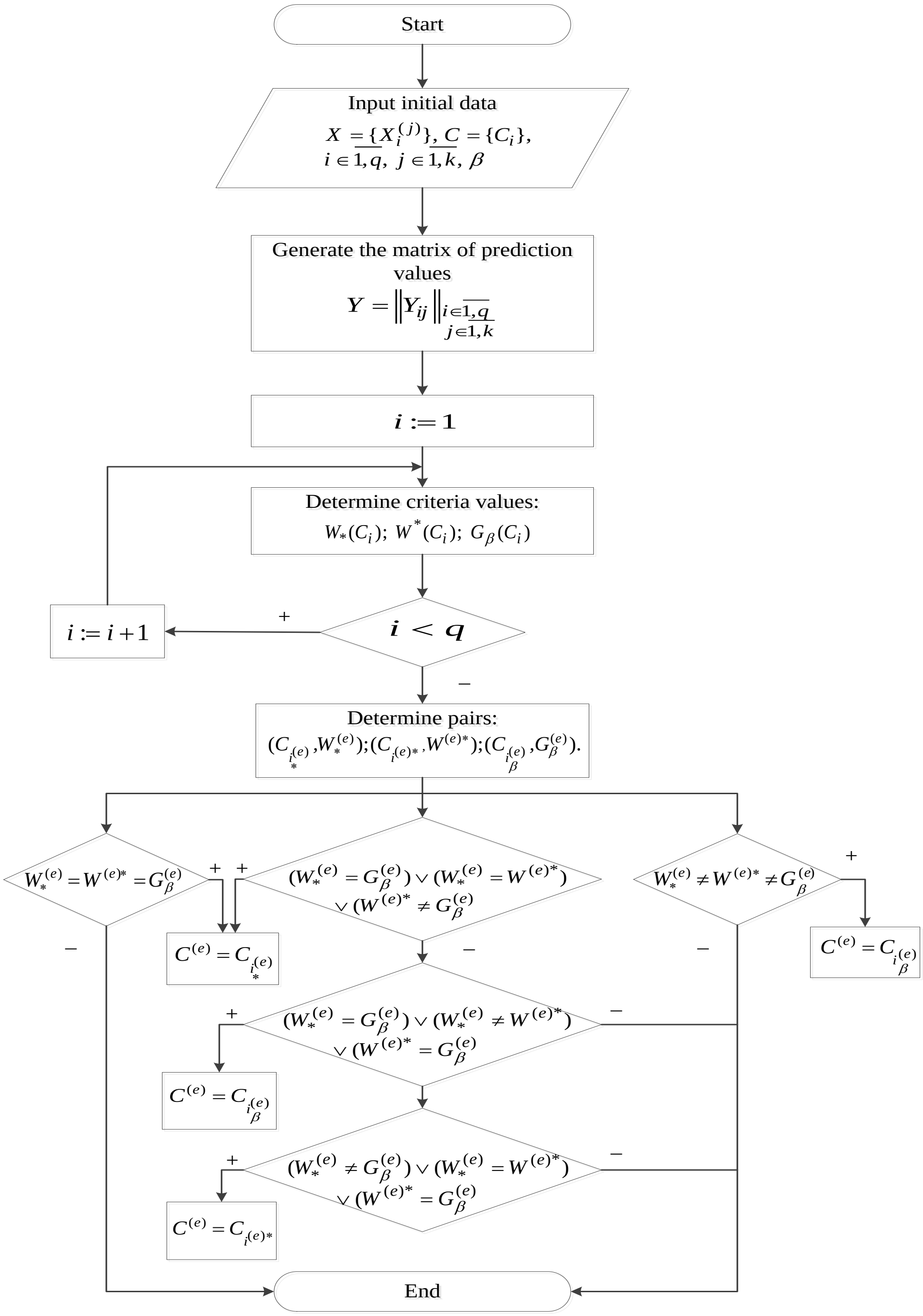
Strategy 3: the price is the same as the competitors currently have;

Strategy 4: the price is 5% lower than the competitors currently have;

Strategy 5: the price is 10% lower than the competitors currently have;

We mean the average price that the competitors have.

The task is to determine an optimal pricing strategy of an enterprise in the current conditions. The earnings maximization is considered to be an optimization criterion in this case.



The flow chart of the algorithm to choose the optimal strategy of the investment projecting control

To make a pay-off matrix, we build a forecast model of sales values using the multiple regression analysis method [16–18].

This method means to determine functional dependences between the function (volume of sales) and factors (realization value, competitors' price, prime cost, advertising expenses, etc.).

The data about volume of sales, realization value, competitors' prices, ad budget, prime cost and consumer price index collected for 24 months are the initial data and are presented in Table 2.

Table 2

Initial data to make an econometric model

Month	Volume of sales, thousands of roubles	Time	Realization value, ₽	Competitors' price, ₽	Advertising expenses, ₽	Prime cost, ₽	Consumer price index, %
July	7992.40	1	6	8	2.049	112.42	100
August	5170.33	2	8	12	2.049	112.42	103.90
September	4212.12	3	8.3	12	2.049	112.23	107.40
October	2137.20	4	8.5	13	1.119	93.00	111.60
November	2980.69	5	9.0	13.5	1.119	93.00	115.70
December	2688.54	6	9.7	13.7	1.119	93.00	117.50
January	2298.15	7	10.0	13.7	0.84	68.85	121.50
February	1435.65	8	10.5	15	0.84	68.85	126.50
March	2190.90	9	10.9	15.5	0.84	68.85	131.40
Aipril	2930.56	10	11.4	15.5	2.53	148.75	137.40
May	4862.85	11	11.8	15.5	2.53	148.75	142.10
June	8345.56	12	12.3	15.5	2.53	148.75	147.80
July	8639.25	13	12.8	15.5	3.28	190.94	153.80
August	5458.16	14	13.3	16	3.28	190.94	156.20
September	4867.32	15	13.9	16.4	3.28	190.94	162.20
October	2540.70	16	14.1	16.4	1.79	127.93	169.20
November	2900.20	17	15.0	16.4	1.79	127.93	174.30
December	2951.43	18	15.6	16.4	1.79	127.93	181.00
January	2391.80	19	16.2	16.8	1.35	112.90	187.70
February	1413.19	20	16.9	16.9	1.35	112.90	195.60
March	2434.05	21	17.5	17.5	1.35	112.90	204.10
Aipril	3140.23	22	18.2	21.2	4.05	241.56	210.90
May	4875.29	23	19.0	21.2	4.05	241.56	213.50
June	8900.32	24	19.7	21.2	4.05	241.56	220.40

When applying the regression analysis, various possible statistically significant models have been considered. From these models in accordance to *F*-test, coefficient of determination and values of balance standard deviation we choose the most valuable factors analysing the significance of the model factors using *t*-index. Thus, the model presented in Table 3 describes the data more efficiently.

Table 3

Regression statistics of forecast model

Index	Index value
Multiple R	0.82
R^2	0.67
Normalized R^2	0.57
Standard error	1439.32
Y-intersection	6184.83
X_1 variable	–571.33
X_2 variable	2420.17
X_3 variable	–1207.06
X_4 variable	16524.67
X_5 variable	–310.87

In accordance to formula (1) and the obtained indices values we create the following model:

$$Y = 6184.83 - 571.33 \times X_1 + 2420.16 \times X_2 -$$
$$-1207.06 \times X_3 + 16524.67 \times X_4 - 310.87 \times X_5,$$

where Y is the volume of sales; X_1 is time; X_2 is the realization value; X_3 is the competitors' price; X_4 is the advertising expenses; X_5 is the consumer price index.

The model we have made has the correlation coefficient $r=0.82$ and accurately reflects sales volume dynamics.

We build a pay-off matrix (Table 4) based on the created forecast model. The matrix reflects the forecast values of sales volumes in October next season considering various strategies and "nature" conditions combination.

Table 4

Pay-off matrix and maximin criterion

Price strategies	Market contitions					Minimum of the line	$W_*^{(e)}$ criterion value
	X_1	X_2	X_3	X_4	X_5		
Strategy 1	7005.26	7069.53	7198.07	7262.34	7390.87	7005.26	7005.26
Strategy 2	6873.36	6936.42	7062.54	7125.59	7251.71	6873.36	-
Strategy 3	6741.46	6803.31	6927.01	6988.86	7112.55	6741.46	-
Strategy 4	6609.57	6670.20	6791.48	6852.12	6973.39	6609.57	-
Strategy 5	6477.67	6537.095	6655.95	6715.38	6834.24	6477.67	-

Thus, the maximin estimation of a control strategy determining the guaranteed upper bound of the forecasted sales volume in the worst implementation conditions of the process under consideration forms strategy 1 and its corresponding sales volume that is equal to ₽ 7005.26.

We calculate the maximax estimation of a control strategy using the data of the same pay-off matrix. This estimation determines the most possible upper bound of the forecasted sales volume at the most favourable condition implementation. Strategy 1 and its sales volume value equal to ₽ 7390.87 correspond to the maximax control strategy (Table 5).

Table 5

Pay-off matrix and maximax criterion

Price strategies	Market conditions					Maximum of the line	$W^{(e)*}$ criterion value
	X_1	X_2	X_3	X_4	X_5		
Strategy 1	7005.26	7069.53	7198.07	7262.34	7390.87	7390.873	7390.87
Strategy 2	6873.36	6936.42	7062.54	7125.59	7251.71	7251.714	-
Strategy 3	6741.46	6803.31	6927.01	6988.86	7112.55	7112.555	-
Strategy 4	6609.57	6670.20	6791.48	6852.12	6973.39	6973.395	-
Strategy 5	6477.67	6537.095	6655.95	6715.38	6834.24	6834.236	-

To make a compromise solution between the pessimistic estimation by the minimax criterion W_* and the optimistic estimation by the maximax criterion W^*, we calculate a value of the Hurwitz criterion $G_\beta^{(e)}$ for each strategy (Table 6).

Table 6

Search of a compromise solution when β=0.75

Price strategies	Compromise	Hurwitz criterion $G_\beta^{(e)}$ value
Strategy 1	7101.66	7101.66
Strategy 2	6967.95	-
Strategy 3	6834.24	-
Strategy 4	6700.52	-
Strategy 5	6566.81	-

On the present table data basis we choose a strategy which compromise solution is maximum. In our case it is strategy 1 and its corresponding Hurwitz criterion value – ₽ 7101.66.

To compare, we make calculations using the pessimism-optimism criterion β=0.25 (Table 7) and β=0.5 (Table 8).

Table 7

Search of a compromise solution when β=0.25

Price strategies	Compromise	Hurwitz criterion $G_\beta^{(e)}$ value
Strategy 1	7294.47	7294.47
Strategy 2	7157.12	-
Strategy 3	7019.78	-
Strategy 4	6882.43	-
Strategy 5	6745.10	-

Strategy 1 and its corresponding Hurwitz criterion value equal to ₽ 7294.47 are the compromise solution based on the calculations with the present pessimism-optimism criterion value.

Table 8

Search of a compromise solution when β=0.5

Price strategy	Compromise	Hurwitz criterion $G_{\beta}^{(e)}$ value
Strategy 1	7198.06	7198.06
Strategy 2	7062.53	-
Strategy 3	6927.01	-
Strategy 4	6791.48	-
Strategy 5	6655.95	-

Correspondingly, strategy 1 and its corresponding Hurwitz criterion value equal to ₽ 7198.06 are the compromise solution when β=0.5.

Thus, when we use the criteria under consideration (the maximin criterion forms strategy 1, the maximax criterion makes strategy 1, the Hurwitz criterion creates strategy 1) we observe the coincidence of these criteria recommendations. In this case the application of strategy 1 is more preforable as this strategy provides an enterprise with the optimal sales volume.

The application of the method developed by the authors allows an enterprise to choose an optimal price strategy considering the impact of external environment on the enterprise activity.

Conclusion

The present research poses the method to choose an optimal control strategy of investment projecting and describes its practical implementation. Features of the suggested method application are discussed in the case study of a particular investment projecting object.

The present method may become the foundation of the development of modern tools of an investment projecting control system. This system will be able to make decisions for practical implementation of particular investment projects.

Further research will be devoted to the improvement of the mathematical apparatus used in the authors' method. In particular, to make the elements of a pay-off matrix it is possible to use neural network simulation techniques as options to the mathematical apparatus of a regression analysis [19–24].

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